MBES Transition to NAVO

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LONG-TERM GOALS

This work supports development of a mine burial prediction capability to be transitioned to the US Navy. State-of-the-art, high-resolution process models are synthesized by a statistical prediction tool (the Mine Burial Expert System—MBES), which relates uncertainty in model input to uncertainty in the predicted mine burial. This work will produce more detailed and more accurate mine burial predictions than are currently available. In addition, the use of Bayesian statistical approach to the problem provides an ability to quantify the risk of encountering any degree of burial.

OBJECTIVES

This effort facilitates the transition of the MBES from the developers (JHU/APL) to the users (NAVO). Specific objectives in support of this goal include (1) evaluation the statistical and numerical implementation of the MBES; (2) development of an objective definition of mine burial that includes a useful notion of risk; (3) development of a meaningful method to display predictions of mine burial and risk; (4) implementation of mine burial predictions over a map region; (5) comparison MBES burial predictions to corresponding NAVO prediction; and (6) evaluation the predictive skill of the MBES in an operational setting.

APPROACH

The MBES utilizes several process-based models developed within the ONR funded Mine Burial Prediction program for predicting mine burial. Neither the models nor the data are perfect due to a range of uncertainties. The MBES is ideally suited to solving this problem because uncertainty in both model and data accuracy can be included in the analysis. This is done by using the models in Monte Carlo simulations that span all possible prediction inputs. Joint probability tables for all possible prediction inputs and corresponding inputs capture the quantitative information in the simulations. New predictions need only specify the expected probability distribution for model inputs, and the MBES computes the corresponding probability distribution of mine burial.

This transition project has taken the MBES and applied it to scenarios that are relevant to NAVO. These analyses have been evaluated for compatibility with present and future NAVO operations. They have been compared to existing mine burial prediction methods. And they have been compared to independent mine burial and other geotechnical data. This has allowed NAVO analysts to understand the powerful capabilities of the MBES and provide feedback to be used in the MBES development.

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WORK COMPLETED

To date this effort has achieved the following accomplishments: (1) continued revision of the Technology Transition Agreement between NAVO and ONR; (2) review and modification of the MBES scientific and technical implementation details; (3) continued development of the JAVA-API interface; (5) development of methodology to pass known sub-model uncertainties (i.e., errors in parameterizations of physical processes) to the MBES; (6) implementation of the impact burial portion of the MBES using data supplied by NAVO; (7) comparison the MBES mine burial prediction to the corresponding NAVO Mine Burial Prediction; (8) development of a stand-alone MBES implementation including GIS format input and output that is compatible with NAVO file format requirements for integration in NAVO's Environmental Post Mission Analysis (EPMA) framework; (9) implementation of the scour burial portion of the MBES; (10) a demonstration/evaluation of the MBES on several data sets, including data that will be part of field experiments sponsored by member so a NATO specialist team; (11) development of several robust statistical analyses to judge both the absolute and relative skill of the MBES predictions; (12) evaluation of the time-evolving scour burial prediction offered by the MBES; and (13) development of MBES documentation. These latter results (12,13) are new results and are highlighted here.

RESULTS

New results in FY07 focused on implementing the scour burial prediction within the MBES framework. Scour burial is a time-dependent process that requires time series of near-bed velocity input to the MBES. The time series can be measured, hindcast, or forecast data. The temporal resolution of the data is assumed to vary. For instance, measured time series are likely to have the highest resolution (e.g., sampled at several Hz), while forecast time series might have the lowest resolution (e.g., climatology sampled monthly). The MBES allows for a choice in resolution. However, we demonstrated that the resolution must be conveyed to the MBES in a manner consistent with the MBES assumptions as follows:

1. The "duration" input to the scour burial module is most usefully interpreted as a computational time step used for forecasting time-varying burial. This comes from the assumption that the forcing input (e.g., tidal current or wave orbital velocity) is constant over the time step.

2. If climatology is used as input, then a number of random conditions should be generated to simulate a time series. For instance, a 1-month prediction would be composed of 15, 2-day simulations.

3. If time series input is used, there may be fluctuations that are nor resolved by the MBES time step and representative values of the forcing time series are used. We used a squared weighting term such that the input to the MBES is defined as $u_{\Delta t}[t, t+\Delta t] = \frac{\overline{uu^2}}{\overline{u^2}}$, where the overbar indicates averaging over measurements from the period t,t+Δt.

Regardless of the source of input velocity data, the MBES scour model must be run repeatedly to preserve any known time variability in the inputs. Figure 1 illustrates the procedure that must be implemented in order to do this.

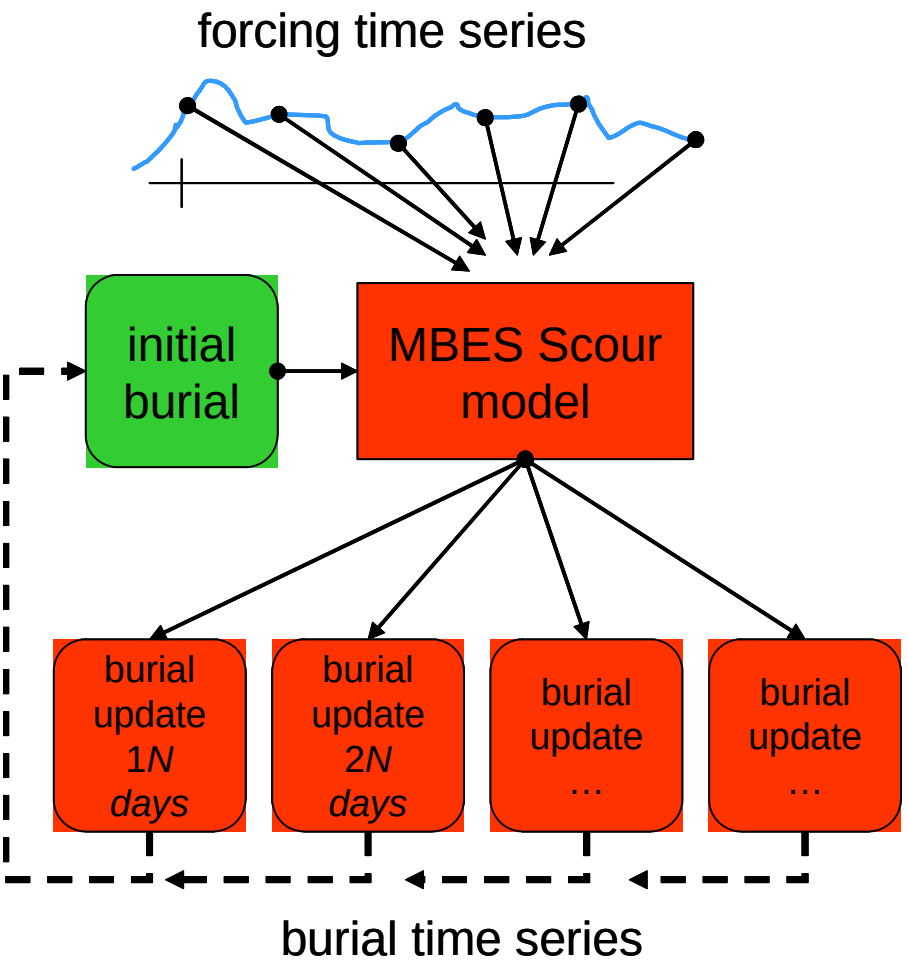

Figure 1. Time stepping approach for implementing scour burial predictions. [this figure shows a flow chart indicating the input source and feedback of the MBES predictions to subsequent predictions]

Figure 2 (top panel) shows a time series of the orbital velocities used to drive the MBES prediction using data from the Indian Rocks field experiment. The dashed line in this panel indicates the threshold velocity that can lead to scour. The bottom panel shows a time series of MBES-predicted probability (as a color map) along with time series of the observed burial (black lines) and time series of some MBES-derived burial statistics (white lines, showing 5th percentile, 95th percentile, and mean burial). The general features of the observed burial are tracked by the confidence limits and mean prediction by the MBES. Note that the observations show significant "unburial". It is not clear whether this is actually lowering of the mine below the ambient seabed or simply filling in of a scour pit around the mine. In any event, the MBES scour model does not attempt to predict "unburial".

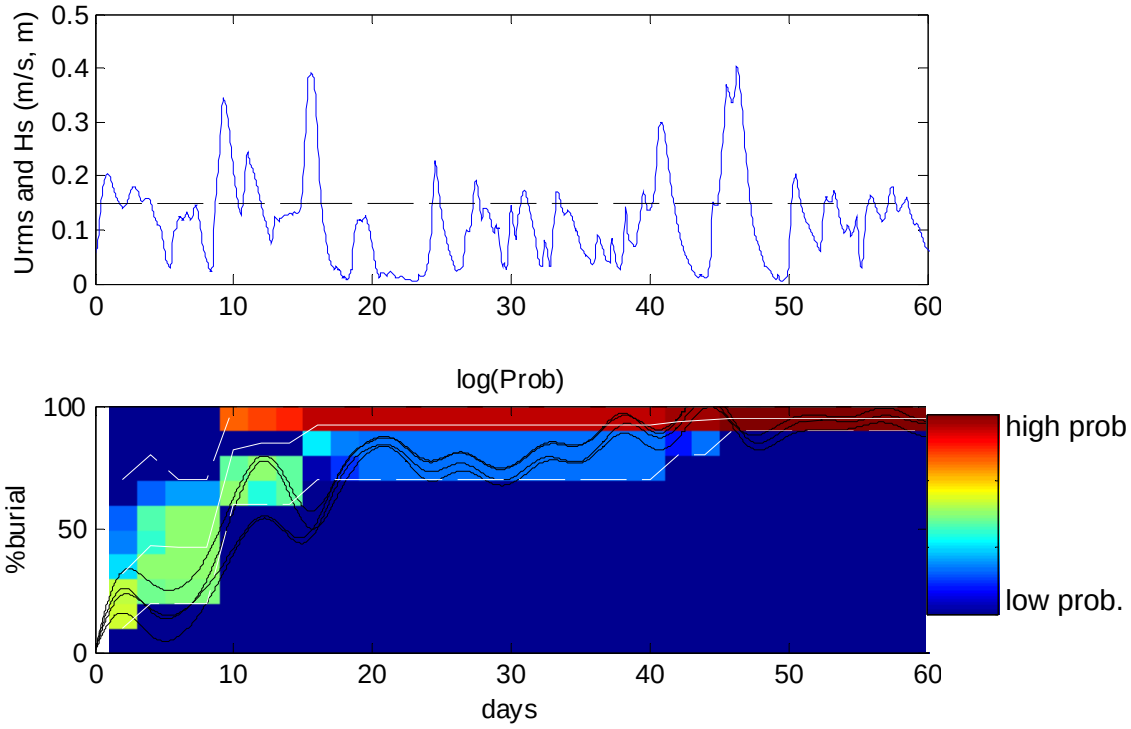

Figure 2. Indian Rocks comparison using 2 day time step. MBES successfully predicts timing and magnitude of increased burial (black line is observed burial from 4 mines) expansion and contraction of uncertaintyDoes not predict "unburial".
[This figure shows a time series of orbital velocity and a corresponding map of probability. The probability of burial is, initially, high at low burial, spreads to intermediate burial, and then is high at high burial]

IMPACT/APPLICATIONS

A number of important conclusions can be drawn from the MBES impact burial evaluation:

1. The MBES can predict variation in impact burial due to intrinsic natural variability in the environment and in mine trajectory.

2. The MBES can predict variations in impact burial due to variations in threat mine type.

3. MBES predictions of mean burial were correlated to observations with a skill exceeding 0.9 (where 1.0 is perfect skill).

4. 0% when observed burial is relatively low (less than 60% burial).

5. The MBES outperformed predictions obtained from NAVOCEANO's existing approach.

6. The uncertainty predicted by the MBES was not well-correlated to the variability of the observed burial. Overall, the MBES slightly under-predicts the observed variability.

A number of important conclusions can be drawn from the MBES scour burial evaluation:

7. The MBES scour module predicts timing and magnitude of increased burial.

8. The MBES scour module predicts expansion and contraction of uncertainty as burial progresses.

9. The MBES scour module does not predict “unburial”

10. Implementation requires a time-stepping approach to represent a time series of forcing by variable wave orbital velocity.

11. MBES assumes steady forcing during a time step.
    a. For a small time step, this assumption is satisfied.
    b. For a large time step (where forcing can vary significantly) a weighted averaged of the forcing is used to drive the model.

12. For forecasting problem where forcing is predicted and is uncertain, a distribution of weighted averaged values will drive the model.

TRANSITIONS

The MBES has transitioned to NAVO and is undergoing integration with the EPMA. This transition was accepted by R. Betsch, MIW Program Manager.

PUBLICATIONS

Rennie, S.E., A. Brandt, and N.G. Plant, A probabilistic expert system approach for sea mine burial prediction, *IEEE Journal of Oceanic Engineering*, 32 (1), 260-272, 2007. [published, refereed]

HONORS/AWARDS/PRIZES

2006 Alan Berman Publication, Naval Research Laboratory
2007 Navy Meritorious Unit Commendation Citation Award, Naval Research Laboratory